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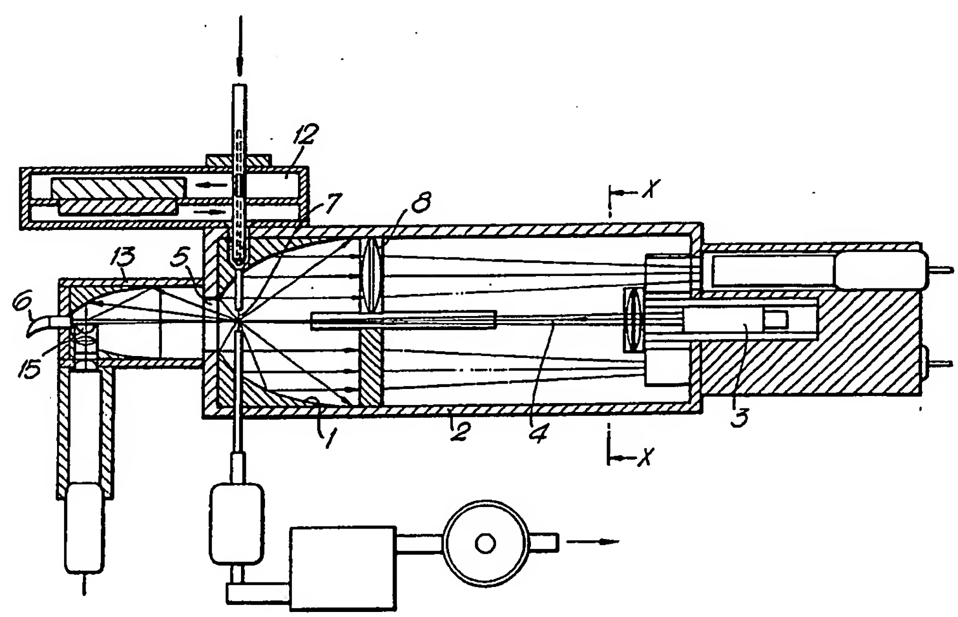
(54) Title: PARTICLE ASYMMETRY ANALYSER



(57) Abstract

An apparatus and method which provides a measure of the asymmetry as well as the size of individual fluid borne particles. Laser-light scattering techniques are employed to obtain data on the particles, which is then compared to data on known particle shapes to ascribe an asymmetry factor to the particles.

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PARTICLE ASYMMETRY ANALYSER

This invention relates to the techniques for the analysis of fluid-borne particles and particularly for looking at the asymmetry of such particles. For example, in the study of aerosols, aerosol dispersions and airborne particulate pollution control, there is a requirement for the rapid determination of particle size distribution especially in the diameter range 1 to 10 microns, together with some knowledge of the geometry and symmetry of individual particles. The latter information could, for example, enable particles with spherical symmetry to be identified and thus allow the counting/monitoring of liquid droplets in an environment including other solid, non-spherical particles. In the context of the present specification, the term particles is intended to apply both to solid bodies and to drops of liquid.

It is desirable for such techniques to be able to count individual particles in a sample at rates of, typically, 20,000 particles per second, to be able to distinguish between spherical and non-spherical particles in the sample and to count each type. Another desirable feature is to categorise spherical particles having diameters of 0.5 - 15 microns into a number of size bands and also in this connection to classify particle coincidences as 'non-spherical' and hence to ignore them in the compilation of size spectra.

The normal techniques for the examination of particles, as used in several instruments available commercially, employ the detection and analysis of electromagnetic radiation scattered by the particles. All such instruments use a mechanical mechanism to drive the sample air through a "sensing volume" where the carried particles are illuminated by the incident electromagnetic radiation. The radiation scattered by the particles is received by one or more detectors which convert the engergy to electrical signals from which information may be extracted by appropriate electrical circuits.

One class of instrument available commercially permits the collection of scattered radiation from large numbers of particles simultaneously, and uses this information to determine a mean figure for particulate mass per unit volume of gas or air, or the statistically averaged size distribution of particulate matter. These instruments are not capable of examining individual particles, and therefore cannot yield accurate particle counts or information relating to particle morphology.

A second class of instrument uses the properties of laminar flow in gases to restrict the particles to a smaller sensing volume and then, by focusing the incident electro-magnetic radiation in some way, is capable of the examination of individual particles, yielding a particle count and possibly approximate size distribution.

The prior art instruments, therefore, will give, to a certain extent, information on particle size and particle count. However, there is no instrument available that is capable of giving information on the asymmetry of individual fluidborne particles.

There is therefore a need for a particle analyser which can analyse individual fluid-borne particles and give information as to the asymmetry of the particles by, for example, ascribing an asymmetry factor to the individual particles.

According to one aspect of the present invention there is provided a particle analyser which comprises means for delivering a sample of fluid in the form of a laminar flow fluid, means for illuminating the sample with a beam of radiation, means for reflecting and directing scattered radiation on to light collectors, means for deriving data from the light collectors to describe the particle where the analyser includes means for comparing the data with data on known shapes to determine the degree of particle asymmetry.

The beam of radiation is preferably provided by a laser, and the scattered radiation is reflected by a concave reflector, preferably an ellipsoid mirror which directs the radiation towards radiation collectors. Radiation scattered at low angles is detected in a second chamber, which leads from an aperture in the ellipsoid mirror, by radiation collectors, preferably optical fibres arranged concentrically around the unscattered beam. The radiation collected is then converted into electrical signals, processed and analysed and by comparing with data on known particle shapes the particles are ascribed an asymmetry factor.

Furthermore, in addition to the asymmetry factor the size of the particle may also be determined. A large number of particles may be ascribed an asymmetry factor, and the cumulative results of this operation coupled with the associated size spectra, could be used to generate a topographical 'thumb print' of the particles in an environment which may be of more value than the data of single particles taken alone.

In looking for sphericity, the criterion for classification for spherical particles can be defined readily as symmetrical scattering about the axis of the illiminating beam of randomly polarised or circularly polarised radiation. Therefore a number of radiation collectors are placed radially symmetrically about the reflection axis of the concave reflector.

In looking for the degree of asymmetry, the arrangement of the collectors could not be assumed to be the optimum for particle asymmetry analysis. The design of the scatter chamber must allow for the flexibility of collector configurations specifically required, and the positions of which to be varied at will.

The advantage of this technique is that, by using optical fibre collection optics, one can readily simulate the effect of placing almost any number of collectors at any position around most of the scattering sphere, a task which would otherwise be mechancially extremely difficult. Thus with a high degree of flexibility, various detection geometries may be tested without the need for mechanical changes to the chamber itself.

According to a second aspect of the present invention a method of determining the asymmetry of fluid-borne particles includes the steps of:-

providing a sample of fluid in the form of a laminar flow;
illuminating the sample with a beam of radiation;
reflecting the radiation scattered by individual particles to radiation collectors;
deriving data from the light collectors describing the particle; and
comparing the data with data on known shapes to determine the degree of particle asymmetry.

The sample may be an aerosol.

Two embodiments of the invention will now be described by way of example only and with reference to the accompany drawings of which:

Figure 1 is a schematic side view in section of a particle analyser for analysing spherical particles.

Figure 2 is a sectional view of the analyser in Figure 1 along the line x-x

Figure 3 is a schematic side view in section of an asymmetry analysis system.

Figure 1 illustrates a basic form of the invention where only spherical particles are analysed in which a parabolic concave reflector (1) is located at one end of a scatter chamber (2). Mounted at the other end of the scatter chamber (2) and aligned with the principal axis of the reflector (1) is a laser (3), which directs a beam of radiation (4) towards a hole (5) in the reflector (1) and chamber (2) at the principal axis of the reflector. After passing through the hole (5) the beam (4) enters a beam dump (6), typically a Rayleigh horn.

A sample (7) of laminar flow air is directed into the chamber (2) to intercept at right angles the laser beam (4) at the focal point of the parabolic reflector (1).

A particle in the sample (7) will deflect the radiation out of the beam (4) onto the reflector (1) which reflects it parallel to the principal axis to radiation collectors (8) adjacent the laser (3). The radiation collectors (8) may be photo multiplier units, optical fibres leading to such units, or lenses for directing the light onto fibres or units.

As shown in Fig 2 three radiation collectors 8 are arranged radially around the beam 4. In such an arrangement symmetrical scattering can be directed which will identify spherical particles. Indeed, any number of radiation collectors 8 may be arranged radially about the beam of radiation 4.

Figure 3 shows a preferred embodiment of a particle analyser according to the present invention which is able to analyse individual particles and ascribe to them an asymmetry factor. In this embodiment, the laser (3) is mounted beneath the chamber (2) and at 90° to principal axis of the reflector (1). The beam (4) being reflected onto the principal axis of the reflector by a prism or mirror (9) suitably positioned on the axis. Indeed, the laser (3) may be mounted just about anywhere about the scatter chamber (2) with a appropriately angled mirror (9) on the axis.

Figure 3 also illustrates the scatter chamber (2) having an eillipsoid reflector (10) with the point of interception between the beam (4) and the sample (7) being one focal point of the ellipse and a collector lens (11) mounted near the second focal point to render parallel the reflected radiation to radiation collectors (8) at the end of the chamber (2). At this point the intensity distribution

represents a spatially modified replica of that scattered into approximately 0.84 of a sphere by the particle. Figure one illustrates the sample (7) of fluid being delivered in laminar flow, by means of a sheath air intake (12) supplying a layer of air at a constant velocity.

A certain amount of difficulty is experienced in capturing and analysing the radiation scattered at low angles to the beam (4) direction. At very low angles (1° to 3°) they are swamped by light scattering from laster focussing optics. To overcome this a second scattering chamber (13) is introduced coaxial to the principal axis of the concave reflector (1) on the main scatter chamber (2). Radiation collectors (8) are suitably placed in this chamber to collect the low angle deflections.

Figure 3 therefore illustrates a second chamber (13) in which optical fibres (14) are arranged around the beam (4). The optical fibres (14) may be arranged in concentric rings around the beam (4). The fibres (4) act as radiation collectors for converting the radiation collected into electrical signals for processing and analysis.

As illustrated in Figure 1, the second chamber (13) may alternatively have a second concave reflector (14), which would normally be ellipsoided, having the point of intersection of the beam (4) and the sample(7) as its second or distal focal point and having a radiation collector (15) at its first or proximal focal point. Thus radiation deflected at low angles will strike the ellipsoidal reflector and be directed onto the radiation collector (15).

The radiation collector (15) may be positioned to face the aperture (5) on the first chamber or may be positioned at 90° to this direction as shown in Figure 1. The latter arrangement would collect relatively more radiation of low angle of deflection, but less overall since only deflections in the direction of the face of the collector will be recorded.

Figure 1 illustrates how in use the sample (7) is supplied in laminar flow by means of a sheath of constant velocity filtered air being supplied around the sample. Thus the outer parts of the sample flow at the same velocity as the inner parts. The outer parts of the sample would otherwise flow more slowly due to friction with the stationary air next to the sample flow. Additionally, and more importantly the coaxial tube supplying the sheath of air is designed

to dynamically focus the particles in the sample to provide a laminar flow of particles. Thus making it easier to line up the particle flow on the focal point of the reflector.

The asymmetry particle analyser operates as follows. The laser beam, produced by a gas laser, enters the chamber at right angles to the reflector axis and is reflected through 90° along the principal axis of the reflector. The radiation scattered by individual particles from approximately 19° to 145° relative to the beam axis is thus reflected onto the aspheric collection lens at the rear of the chamber. This lens renders the emerging light parallel, and the intensity distribution across this output window represents a spatially modified replica of that scattered into approximately 0.84 of a sphere by the particle.

With the collected light in the form described above, the positions of the optical fibre detectors to measure the light distribution may be varied at will.

To determine particle sphericity the detectors would be placed symmetrically about the axis of the output window.

In this way, with the use of optical fibre optics, one can readily simulate the effect of placing almost any number of detectors at any position around most of the whole scattering sphere.

Based upon the results of theoretical models and experimental results of scattering patterns of known shapes, algorithms are used to ascribe to particles an asymmetry factor.

The processing of data from particles to determine their asymmetry could be handled by a transputer as produced for example by the British Inmos chip manufacturers.

One transputer is used for each detection channel. In this way, tasks hitherto performed serially on incoming data from channels could be performed on all channels simultaneously giving a substantial increase in data throughput.

Although this invention has been described by way of example and with reference to possible embodiments thereof, it is to be understood that modifications or improvements may be made without departing from the scope of the invention as defined in the appended claims.

CLAIMS

1. A particle analyser including:

   means for providing a sample of fluid in the form of a laminar flow;

   means for illuminating the sample with a beam of radiation;

   means for directing the radiation scattered by individual particles towards radiation collectors;

   means for deriving data from the radiation collectors to describe the particle; wherein the analyser also includes

   means for comparing the data with data or known shapes to determine the degree of particle asymmetry.

2. A particle analyser as claimed in Claim 1 wherein the illuminating beam is provided by a laser.

3. A particle analyser as claimed in Claim 1 or Claim 2 wherein the means for directing the radiation is a concave reflector.

4. A particle analyser as claimed in Claim 3 wherein the concave reflector is an ellipsoid reflector.

5. A particle analyser as claimed in any previous claim wherein the radiation collectors are optical fibres leading to photomultipliers.

6. A particle analyser as claimed in any previous Claim wherein the radiation collectors may take any configuration and their positions may be varied at will.

7. A method in determining the asymmetry of fluid borne particles including the steps of:-

   providing a sample of fluid in the form of a laminar flow;

   illuminating the sample with a beam of radiation;

   reflecting the radiation scattered by individual particles to radiation collectors;

   deriving from the collectors data describing the particle; and

   comparing the data with data on known shapes to determine the degree of particle asymmetry.

8. A method as claimed in Claim 7 where the fluid is an aerosol.

9. A method as claimed in Claim 7 or Claim 8 wherein the illuminating beam is provided by a laser.

10. A method as claimed in any one of Claims 7 to 9 wherein the radiation scattered by individual particles is reflected by a concave reflector towards the light collectors.

11. A method as claimed in Claim 10 wherein the concave reflector has an ellipsoid interior surface.

12. A method as claimed in any one of Claims 7 to 11 wherein the radiation collectors are optical fibres connected to photomultipliers.

13. A particle analyser substantially as herein described with reference to the accompanying drawings.

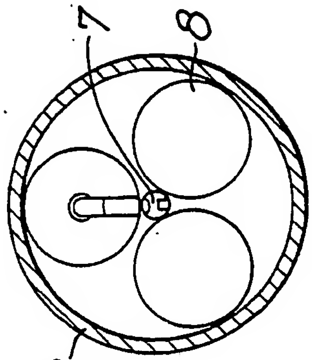


Fig.2.

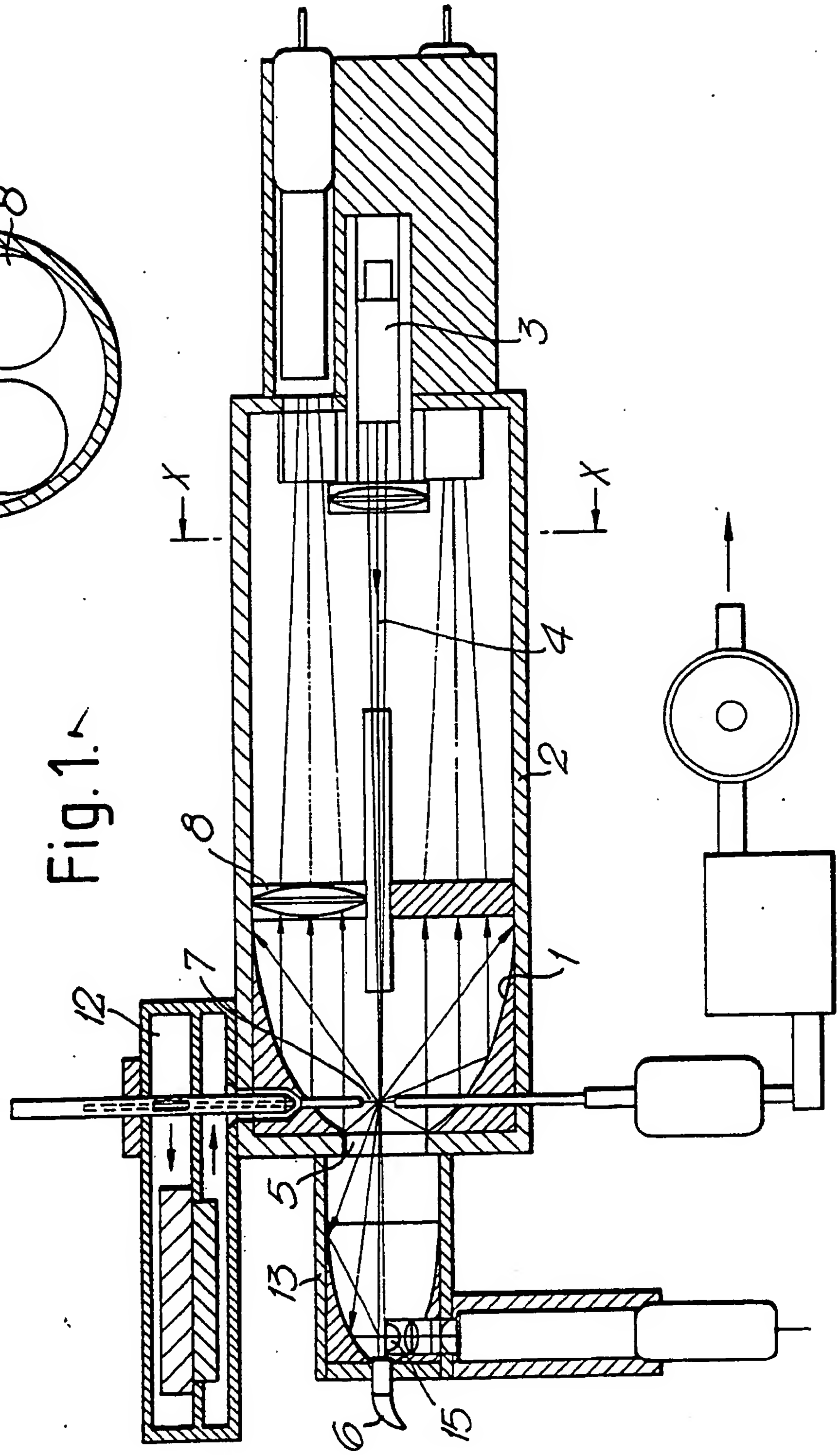
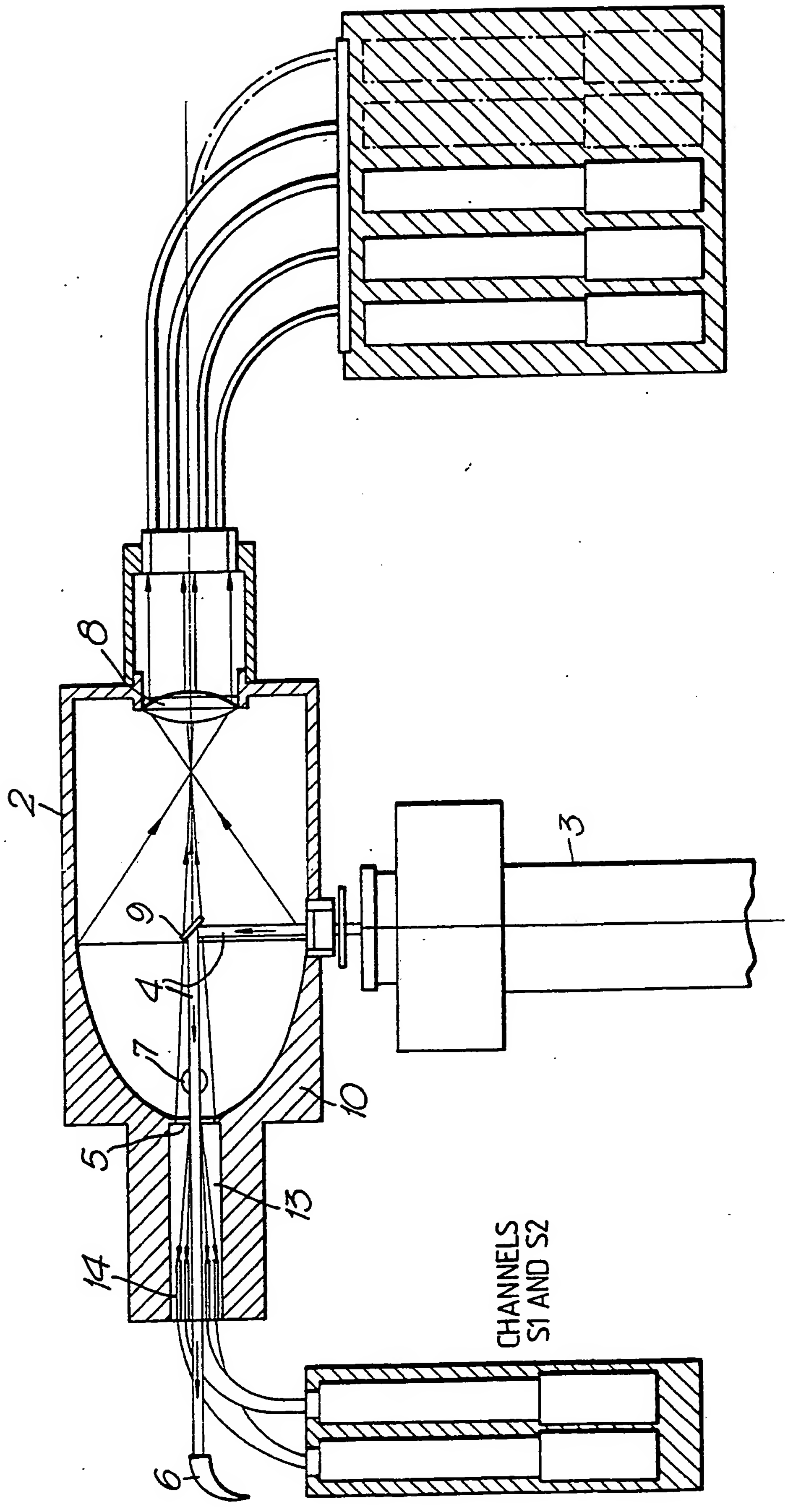


Fig.1.

Fig.3.



INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 88/00975

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[4]: G 01 N 15/02

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC[4]	G 01 N 15/02; G 01 N 15/14

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	US, A, 4606636 (J. MONIN et al.) 19 August 1986 see column 2, lines 28-68, column 3; column 4, lines 1-65	1-7,9-12
X	K.R. Spurny: "Physical and Chemical Characterization of Individual Airborne Particles", 1986, (Chichester, Ellis Horwood, GB), J. Allen: "Size and shape measurement of individual aerosol particles by asymmetric laser light scattering", pages 101-115 see pages 102-103, paragraph 6.2; pages 105-107, paragraphs 6.5-6.7	1,2,7-9
A	GB, A, 2041516 (COULTER ELECTRONICS) 10 September 1980 see page 5, lines 123-130; page 6; page 7, lignes 1-89; figures 1,3,4	1,3,4,10, 11
A	FR, A, 2535051 (UNIVERSITE DE SAINT ETIENNE) 27 April 1984 ./.	1,5,10,12

* Special categories of cited documents: [10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
8th February 1989	- 1. 03. 89
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	P.C.G. VAN DER PUTTEN

International Application No. PCT/GB 88/00975

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
	see page 6, lines 19-37; page 7; page 8, lines 1-27 --------	

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. GB 8800975

SA 25163

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 23/02/89
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